<u>ASCE 7 and Building Code Update</u>

ASCE 7 Tsunami Loads and Effects Subcommittee
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The Code Development Process:

Improvements in disaster resilience and life safety in the built environment are achieved through a continual code development process involving public agencies, academic institutions, private industry structural engineering experts, and construction and material industry associations. These entities are involved in the three principal undertakings of

1. research & development,
2. Implementation of codes and standards, and
3. learning from design experience and post-disaster building performance reconnaissance.

Research encompasses a great range of activities, not all of which are practical from the standpoint of building codes. Since building codes constitute mandatory requirements for design and construction, for natural hazards sufficient justification must include quantitative engineering risk analysis for the basis of design. All engineering design is essentially based on targeting a reliability level for the performance of the facility for a probabilistically defined hazard. That is, the probability of the hazard exceeding the structure's limit state is standardized to a targeted small chance over the lifetime of the facility. This is only possible to quantify when the hazard is estimated probabilistically, i.e., the parameter of hazard intensity (such as tsunami amplitude) is calculated as a function of the annual probability of exceedance.

Therefore, engineers involved in code development tend to view research in the following hierarchy:

- Hypothetical Hazards: a mechanism to generate a hazard is postulated
- Historical and Paleo Hazards: evidence of this mechanism is found to have occurred
- Hazard Assessment: the range of intensity of this hazard is estimated based on the mechanism and past occurrences are compiled
- **Probabilistic Hazard Analysis: the intensity of hazard is estimated with respect to annual odds of exceedance**
- Vulnerability and Exposure Assessment: the extent of possible effects of the hazard on infrastructure and society are evaluated
- **Vulnerability Analysis:** the losses anticipated for postulated hazard levels are quantified
- **Engineering Risk Analysis: the probabilities of exceeding quantifiable losses are calculated based on convolving the hazard and vulnerability analyses.**

The "price of admission" for including a hazard in a building code is recognized literature that provides a probabilistic hazard analysis and a vulnerability analysis so that the risk to society can be measured and compared to the risks of other hazards.

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In the United States, the national model building code is the International Building Code (IBC), promulgated by the International Code Council.To ensure that the constructed facility meets the design intent, the requirements of the code are coordinated throughout referenced standards to provide an accepted and recognized American system of design and construction quality management.

The IBC references design provisions for building and other structures that are given in American Society of Civil Engineers Standard 7, Minimum Design Loads for Buildings and Other Structures(ASCE-7). The ASCE 7 Standard becomes part of an enacted building code law through adoption of the model code by the local authority having jurisdiction (such as a state, county, or city). The ASCE Codes and Standards Activities Division is responsible for developing the final design standards under rules for consensus-based standards. Decision-making ASCE committees are composed of 1/3 academic, 1/3 professional engineers with relevant expertise, and 1/3 technical representatives from industry and material associations.

The IBC and ASCE 7 also reference other consensus-based design standards and specifications. Other standards also referenced in the code include more detailed requirements for material specifications, and installation procedures given in the ASTM International set of standards and Underwriters Laboratory and so forth. Procedures for testing and qualification of materials, equipment, and systems also exist for quality assurance to verify that materials and products meet the requirements of the building code.

Guidelines have no force of law and do not result in a standard of practice.A local jurisdiction must adopt the International Building Code as its local building code in order for it to be enforceable. The local adoption of a national model code often incorporates local amendments that take into account more detailed information on hazards and environmental conditions.The local adoption of a national model code often incorporates local amendments that take into account more detailed information on hazards and environmental conditions of the local region.

Learning from design experience and the performance of structures during disasters is the key of ultimate validation, which is why the FEMA, ASCE, and others place high importance on post-disaster inspections. Lessons learned from disasters may foster new research or may be immediately implemented in the code.

Tsunami Codes:

A national standard for engineering design for tsunami effects written in mandatory language does not exist. As a result, tsunami risk to coastal zone construction is not explicitly and comprehensively addressed in design codes.The Tsunami Loads and Effects Subcommittee of the ASCE/SEI 7 Standards Committee is developing a proposed new Chapter 6 - Tsunami Loads and Effects, with Commentary for the 2016 edition of the ASCE 7 Standard.ASCE 7-2016 Chapter 6 would provide prescriptive loads for tsunami and its effects, and it will also incorporate aspects of Performance Based Tsunami Engineering.

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Overarching perspective on tsunami performance objectives and their applicability to different Risk Category buildings;

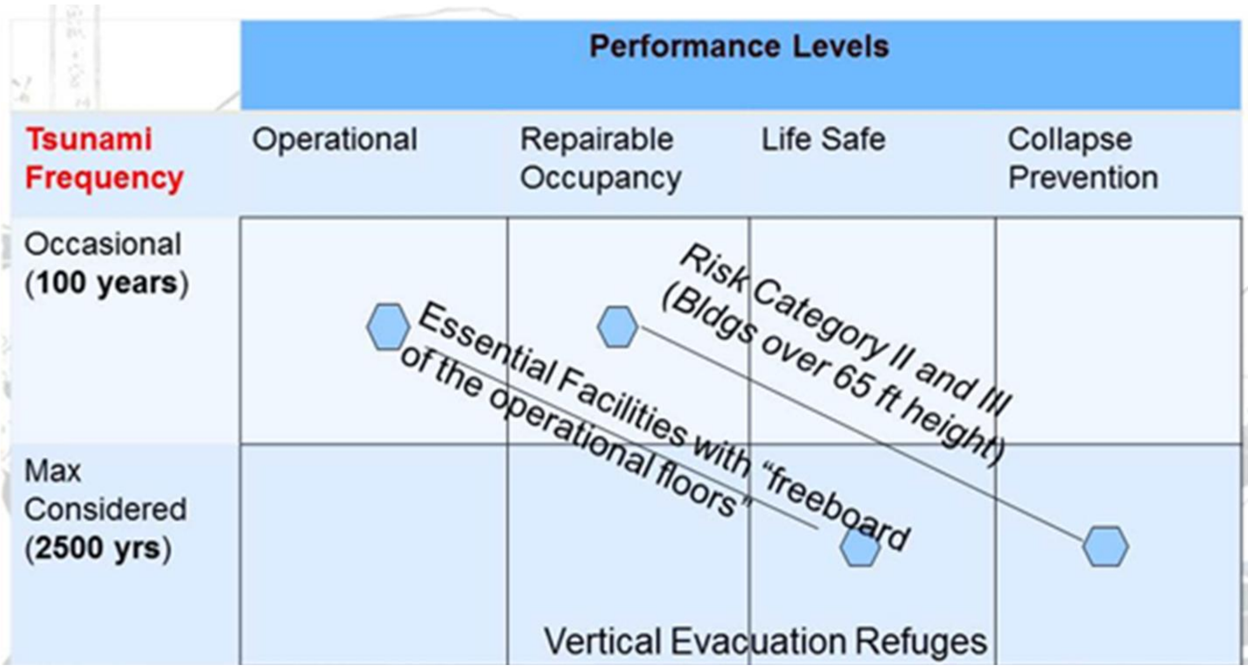
The ASCE 7 Standard classifies facilities in accordance with Risk Categories that recognize the importance or criticality of the facility.The design requirements in the ASCE 7 Standard vary by Risk Category so that a higher level of reliability can be achieved.

Risk Category I	**Buildings and other structures that represent a low risk to humans**
Risk Category II	**All buildings and other structures except those listed in Risk Categories I, III, IV**
Risk Category III	**Buildings and other structures with potential to cause a substantial economic impact and/or mass disruption of day-to-day civilian life in the event of failure.**
Risk Category IV	**Buildings and other structures designated as essential facilities**

It is presently anticipated that the ASCE 7 Tsunami Loads and Effects Chapter will be applicable only to the states and territories with *quantifiable probabilistic hazard*, i.e., Alaska, Washington, Oregon, California, Hawaii, and Guam, American Samoa, and Puerto Rico.

- Not applicable to any buildings within the scope of the International Residential Code,
- Not applicable to Risk Category I structures
- Not applicable to any Risk Category II structures up to ~65 feet in height,
- Applicable to Risk Category III and IV buildings and structures, and Risk Category II buildings of height sufficient for reliable life safety and reasonable economy (probably those of height > 65 ft.)

These following tsunami design performance objectives are somewhat similar, but different in certain respects from typical Seismic Performance objectives. What is common in concept is that there are means to generate estimated hazard curves and building performance levels. For essential facilities and this new occupancy of vertical evacuation shelters, which are anticipated to remain occupied in the upper floors, the performance objectives are also consistent with the objectives typically appropriate for seismic engineering.



- **Performance criteria to be based on 2,500-year hazard level Maximum Considered Tsunami for consistency with ASCE 7 seismic hazard criteria with tsunami as a coseismic effect.**
- **A probabilistic Hazard Map of offshore tsunami height is being developed and will be incorporated in the Standard as a probabilistic benchmark for local inundation mapping products.**
- **The tsunami hazard inland inundation limiting zone affected at the 2,500-year level would be identified.**
- **Criteria will identify where ground shaking and subsidence from a preceding local offshore Maximum Considered Earthquake needs to be considered prior to tsunami arrival (for Alaska and the regions directly affected by the Cascadia Subduction Zone).**
- **local tsunami inundation mapping of hydrodynamic loading parameters, based on probabilistic regional offshore tsunami heights**

The maximum considered tsunami of 2,500 years expected return period can be estimated for tsunamis generated by subduction earthquakes, and it is consistent with seismic design criteria. We select another return period for the occasional tsunami that align better with flood criteria, since there will be a desire to compare the two effects on the same structure.

When communities are enabled with tsunami warning systems with emergency operations plans for evacuation, and public awareness, Risk Category II and III buildings are not occupied during a tsunami. Thus, the "Basic Safety Objective performance points of seismic engineering do not necessarily apply. Therefore, these structures have more limited performance objectives, and the "Life Safe" performance level is more indicative of the degree of damage and expected economic loss rather than actual life safety. The objectives shown for the Risk Category II and III buildings are for distant tsunami hazards.

For coastal communities with special hazard governed by locally generated tsunamis and large subduction earthquakes, more stringent design objectives could be adopted.

Special Design Considerations for Tsunamis:

- For Pacific NW regions governed by nearby offshore earthquakes, structure will need to resist earthquake prior to onset of tsunami.
- Tsunami wave height not proportional to EQ magnitude
- Include possible earthquake-induced subsidence affecting tsunami inundation
- Flow acceleration in urban landscapes
- Analyze the key loading phases of depth and velocity in momentum flux pairs
- Tsunami forces not proportional to building mass
- Inflow and outflow characteristics will be different
- Debris accumulation and low-speed debris impacts
- Scouring at the perimeter of the building

Outline of the proposed scope of the ASCE 7 Standard of Tsunami Loads and Effects:

- 6.1 General Requirements
- 6.2 Definitions
- 6.3 Symbols and Notation
- 6.4 General Tsunami Design Criteria
- 6.5 Procedures for Tsunami Hazard Assessment
- 6.6 Procedures for Tsunami Inundation Analysis
- 6.7 Design Parameters for Tsunami Flow over Land
- 6.8 Design Procedure for Tsunami Inundation (Prescriptive)
- 6.9 Hydrostatic Loads
- 6.10 Hydrodynamic Loads
- 6.11 Impact Loads
- 6.12 Foundation Design
- 6.13 Structural countermeasures for reduced loading on buildings
- 6.14 Special Occupancy Structures
- 6.15 Designated Nonstructural Systems (Stairs, Life Safety MEP)
- 6.16 Non-building critical facility structures
- Commentary and References

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Indications from Prototype Designs of Risk Category IV and III Buildings for Tsunami

- Low-rise and lower-mass buildings could be governed by tsunami, especially port facilities.
- Tsunami collapse prevention:
  - Mid to High-rise design for high seismic conditions may not require any systemic upgrading.
  - Structural Components may need local “enhanced resistance”
  - Ground level shear walls may also require localized detailing for out-of-plane hydrodynamic forces or pressurization effects
  - Vertical refuge appears to be a practical alternative use for mid to high-rise concrete buildings that have greater inherent resistance.
- The expected post-earthquake damage state needs to be considered in design to determine the usable inelastic capacity remaining during near-source tsunami inundation.

Recent Developments in Support of Tsunami Code Development:

A method of probabilistic tsunami hazard analysis has been established in the recognized literature that is generally consistent with probabilistic seismic hazard analysis in the treatment of uncertainty.

Methodologies for 2D tsunami inundation modeling have been further developed and utilized for various designated communities and regions.

Structural loading and analysis techniques for determining building performance have been developed and are proceeding toward formal codification adoption by 2016. Experimental and field validation studies of these techniques have been performed.

Measures of seismic performance in the inelastic range have been developed that appear to have relevant application for tsunami performance metrics in estimating losses.